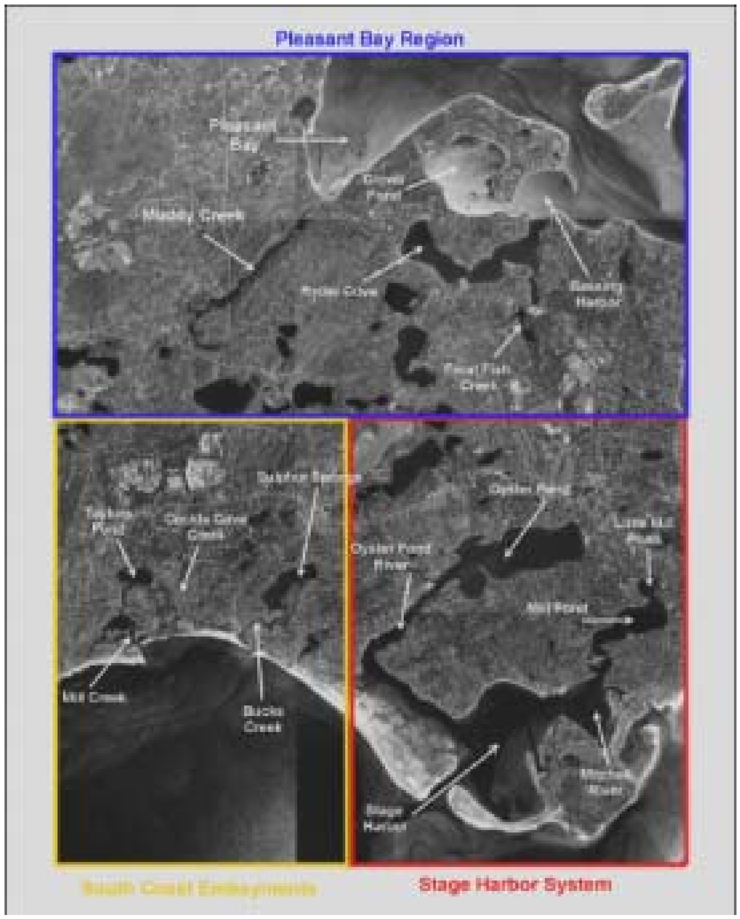
# DRAFT
# Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor and Muddy Creek Total Maximum Daily Loads For Total Nitrogen

**(Report # MA96-01-2004-01**
**Control # CN206.0)**

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# EXECUTIVE SUMMARY

## Problem Statement

Excessive nitrogen (N) originating primarily from septic systems has lead to significant decreases in the "environmental quality" of coastal rivers, ponds, and harbors within the Town of Chatham. The problems in these embayments include:

- Loss of some eelgrass beds, which are critical habitats for macroinvertebrates and fish
- Undesirable increases in macro algae, which are much less beneficial than eelgrass
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life
- Reductions in the diversity of benthic animal populations
- Periodic algae blooms

Some of the most severe, additional problems include:

- Periodic fish kills
- Unpleasant odors and scum
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities

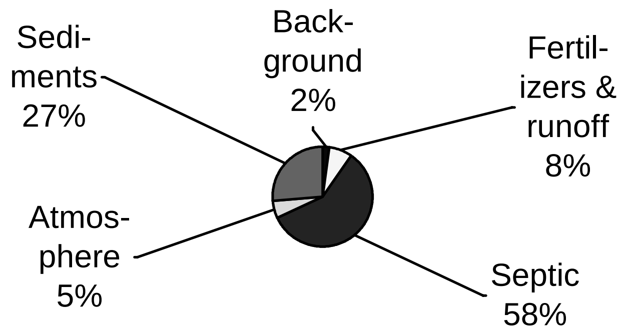
Coastal communities, including Chatham, rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as commercial fin fishing and shellfishing. Failure to reduce and control nitrogen loadings will result in complete replacement of eelgrass by macro-algae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a complete loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of Chatham's coastal waters will be greatly reduced, and could cease altogether.

## Sources of nitrogen

Nitrogen enters the waters of coastal embayments from the following sources:

- The watershed
    - Septic systems
    - Natural background
    - Runoff
    - Fertilizers
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments

Most of the present nitrogen load originates from individual subsurface wastewater disposal (septic) systems, primarily serving individual residences, as seen in the following figure.




**Target "Threshold" Nitrogen Concentrations and Loadings**

The nitrogen loadings (the quantity of nitrogen) to Chatham's embayments presently range from 3.45 kg/day in Frost Fish Creek, to 39.9 kg/day in Oyster Pond. The resultant concentrations of nitrogen in the embayments range from 0.42 mg/L (milligrams of nitrogen per liter) in Ryder Cove to 1.69 mg/L in the Sulphur Springs system.

In order to restore and protect Chatham's embayments, nitrogen loadings, and subsequently the concentrations of nitrogen in the water, must be reduced to levels below the "thresholds" that cause the observed environmental impacts. Scientists have determined that, for Chatham, nitrogen concentrations in the range from 0.38 to 0.552 mg/L are protective. The mechanism for achieving these target nitrogen concentrations is to reduce the nitrogen loadings to the embayments. Scientists have determined through mathematical modeling that the total maximum daily loads (TMDL) of nitrogen that would result in the "safe" target concentrations range from 1.85 to 13.82 kg/day. The purpose of this document is to present TMDLs for each embayment and to provide guidance to the Town on possible ways to reduce the nitrogen loadings to meet, or "implement", these proposed TMDLs.

**Implementation**

The primary goal of implementation will be lowering the concentrations of nitrogen by greatly reducing the loadings from septic systems. This can be accomplished by a variety of methods such as sewering and treatment of sewage and/or septage at centralized or decentralized facilities (with nitrogen removal technology, upgrade/repairs of failed systems, and/or installation of nitrogen-reducing septic systems. These strategies, plus ways to reduce nitrogen loadings from stormwater runoff and fertilizers, are explained in detail in the "MEP Embayment Restoration Guidance for Implementation Strategies", which is available on the DEP website. The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an "adaptive management" approach.

There is presently only one wastewater treatment facility in Chatham, which discharges approximately 3 kg N/day into the groundwater adjacent to Cockle Cove Creek. Indications are that maintaining the present loading rates from the treatment facility will protect the well- functioning salt marshes along Cockle Cove Creek, as well as the rest of the Sulphur Springs embayment system.

Finally, growth within Chatham, which would exacerbate the problems associated with nitrogen loadings, should be guided by considerations of water quality-associated impacts.

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## Introduction

Section 303(d) of the Federal Clean Water Act requires each state (1) to identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL "allocation" establishes the maximum loadings (of pollutants of concern), from all contributing sources, that a water body may receive and still meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.

2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point (sources from discernable, confined, and concrete conveyances such as through a pipe) and non-point sources (diffuse sources that is carried to surface waters by runoff or ground water).

3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body may receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.

4. Specification of load allocations, based on the loading capacity determination, for non-point sources and point sources, that will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDL will serve as a guide for future implementation activities. The DEP will work with Towns to develop specific implementation strategies to reduce nitrogen loadings, and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the specific case of Chatham, the pollutant of concern, relative to this TMDL (based on observations of eutrophication), is the nutrient nitrogen. Nitrogen is considered the limiting nutrient in coastal and marine waters, which means that as its concentration is increased, so is the amount of plant matter. This can lead to nuisance populations of macro-algae, increased concentrations of phytoplankton and epiphyton (which impair eelgrass beds) - all of which combine to imperil the healthy ecology of the affected water bodies.

The TMDLs for total nitrogen for the five coastal embayments within the Town of Chatham, Massachusetts are based primarily on data collected, compiled, and analyzed by U Mass Dartmouth's School of Marine Science and Technology (SMAST), the Cape Cod Commission, and others, as part of the Massachusetts Estuaries Program (MEP). The accompanying technical report presents the results of the analyses of these five coastal embayments using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model). The analyses were performed to assist the Town with up-coming nitrogen management decisions associated with the Town's current and future wastewater planning efforts, as well as wetland restoration, anadromous fish runs, shell fishery, open-space, and harbor maintenance programs. A critical element of this approach is the assessments of available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure that were conducted on each embayment. These assessments served as the basis for generating nitrogen loading thresholds for use as goals for watershed nitrogen management. The TMDLs are based on the site specific thresholds generated for each embayment. Thus, the MEP offers a science-based management approach to support the Town of Chatham's wastewater management planning and decision-making process.

## Description of Water Bodies and Priority Ranking

Chatham Massachusetts, at the eastern end of Cape Cod, is surrounded by water on three sides, with Nantucket Sound to the south, the Atlantic Ocean and Chatham Harbor to the east, and Pleasant Bay to the north. Much of the shoreline, especially to the north and south, consists of a number of small embayments of varying size and hydraulic complexity, characterized by limited rates of flushing, shallow depths and heavily developed watersheds. These embayments constitute important components of the Town's natural and cultural resources. The nature of enclosed embayments in populous regions brings two opposing elements to bear; 1) as protected marine shoreline they are popular regions for boating, recreation, and land development and 2), as enclosed bodies of water, they may not be readily flushed of the pollutants that they receive due to the proximity and density of development near and along their shores. In particular, the embayments along Chatham's shore are at risk of further eutrophication from high nutrient loads in the groundwater and runoff from their watersheds. Because of excessive nutrients many embayments or sub-embayments are already listed as waters requiring TMDLs (Category 5) in the MA 2002 Integrated List of Waters, as summarized in Table 1.

A complete description of the water bodies is presented in Chapters I and IV of the accompanying technical report from which the majority of the following information is drawn. TMDLs were prepared for 17 ponds, rivers, creeks, and harbors listed below. Analytical and modeling efforts were conducted by grouping these 17 "sub-embayments", where appropriate, into embayment systems in which all the sub-embayments of an individual watershed combine to flow into either Nantucket Sound to the south or Pleasant Bay to the North.

- Stage Harbor System:
    - Oyster Pond
    - Oyster Pond River
    - Stage Harbor
    - Mitchell River
    - Mill Pond
    - Little Mill Pond
- Sulphur Springs System:
    - Sulphur Springs
    - Bucks Cr
    - Cockle Cove Cr
- Taylors Pond System:
    - Mill Cr
    - Taylors Pond

- Bassing Harbor System:

  - Crows Pond
  - Ryder Cove
  - Frost Fish Cr
  - Bassing Harbor

- Muddy Creek

  - Lower Muddy Cr
  - Upper Muddy Cr

The embayments addressed by this document are high priorities based on the initiative that the Town has taken to assess the conditions of embayments and the commitment made to restoring and preserving their embayments, and because of the extent of eutrophication in the embayments. In particular, the embayments within the Town of Chatham are at risk of further degradation from increased nitrogen loads entering through groundwater and surface water from their increasingly developed watersheds. In both marine and freshwater systems, an excess of nutrients results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources.

**Table 1. Chatham embayments in Category 5 of the Massachusetts 2002 Integrated List[1]**

| NAME | SEGMENT ID | DESCRIPTION | SIZE | Pollutant Listed |
|---|---|---|---|---|
| **Stage Harbor** | | | | |
| Oyster Pond | MA96-45_2002 | Including Stetson Cove | 0.21 sq mi | Nutrients & Pathogens |
| Oyster Pond River | MA96-46_2002 | Outlet of Oyster Pd to confluence with Stage harbor, Chatham | 0.14 sq mi | Nutrients & Pathogens |
| Stage Harbor | MA96-11_2002 | From the outlet of Mill Pd (including Mitchell River) to the Confluence with Nantucket Sound at a line from the southernmost point of Harding Beach southeast to the Harding Beach Point, Chatham | 0.58 sq mi | Nutrients & Pathogens |
| Mill Pond | MA96-52_2002 | Including Little Mill Pond (PALIS #96174), Chatham | 0.06 sq mi | Nutrients |
| **Sulphur Springs** | | | | |
| Harding Beach Pond | MA96-43_2002 | Locally known as Sulfur Springs (northeast of Bucks Cr), Chatham | 0.07 sq mi | Pathogens |
| Bucks Creek | MA96-44_2002 | Outlet from Harding Beach Pond (locally known as Sulfur Springs) to confluence with Cockle Cove, Chatham | 0.02 sq mi | Pathogens |
| **Taylors Pond** | | | | |
| Mill Creek | MA96-41_2002 | Outlet of Taylors Pond to confluence with Cockle Cove, Chatham | 0.03 sq mi | Pathogens |
| Taylors Pond | MA96-42_2002 | Chatham | 0.02 sq mi | Pathogens |
| **Bassing Harbor** | | | | |
| Crows Pond | MA96-47_2002 | To Bassing Harbor, Chatham | 0.19 sq mi | Nutrients |
| Ryder Cove | MA96-50_2002 | Chatham | 0.17 sq mi | Nutrients & Pathogens |
| Frost Fish Creek | MA96-49_2002 | Outlet from cranberry bog northwest of Stony Hill Road to Confluence with Ryder Cove, Chatham | 0.02 sq mi | Nutrients & Pathogens |
| **Muddy Creek** | MA96-51_2002 | Outlet of small unnamed pond south of Countryside Drive and north-northeast of Old Queen Anne Road to mouth at Pleasant Bay, Chatham | 0.05 sq mi | Pathogens |

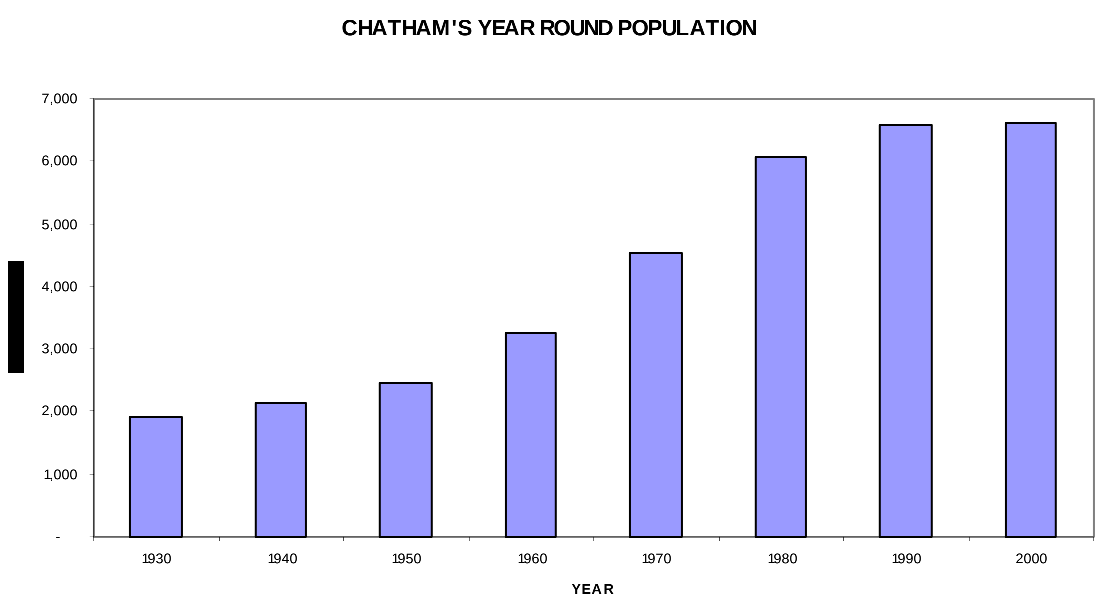
[1] This list was developed prior to the completion of data collection activities and will be reassessed based on the data and information collected during this project.

# Problem Assessment

The Watersheds of Chatham’s estuaries have all had rapid and extensive development of single-family homes and the conversion seasonal into full time residences. This is reflected in a substantial transformation of land from “forest” to “suburban” use between the years 1951 to 2000. Water quality problems associated with this development result primarily from septic systems, and to a lesser extent, from runoff - including fertilizers - from these developed areas.

Septic system effluents discharge to the ground, enter the groundwater system, and in the sandy soils of Cape Cod, travel towards the coastal waters at an average rate of one foot per day. The nutrient load to the groundwater system is directly related to the number of subsurface wastewater disposal systems, which in turn are related to the population. The population of Chatham, as with all of Cape Cod, has increased markedly since 1950. In the particular case of the Town of Chatham, the increase is on the order of 250% since 1950. In addition, summertime residents and visitors swell the population of the entire Cape by about 300% according to the Cape Cod Commission (http://www.capecodcommission.org/data/trends98.htm#population).

The increase in year round residents is illustrated in the following graph:




Based on current local zoning, the populations in the various embayments discussed here could increase from a low of about 4 % to a high of 20% depending on the particular waterbody.

Dramatic declines in water quality, and the quality of the estuarine habitats, throughout Chatham, have paralleled the population growth of the Town. The problems in these embayments generally include periodic decreases of dissolved oxygen, decreased diversity of benthic animals, and periodic algae blooms. Eelgrass beds, which are critical habitats for macroinvertebrates and fish, have significantly declined in these waters. Furthermore, eelgrass is being replaced by macro algae, which are undesirable, because they do not provide high quality habitat for fish and invertebrates. In the most severe cases there would be periodic fish kills, unpleasant odors and scums, and near loss of the benthic community and/or presence of only the most stress-tolerant species of benthic animals.

Coastal communities, including Chatham, rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as commercial fin fishing and shellfishing. The continued degradation of Chatham's coastal embayments, as described above, will significantly reduce the recreational and commercial value and use of these important environmental resources.

Habitat and water quality assessments were conducted on each embayment based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. The five-embayment systems in this study display a range of habitat quality, both between systems and along the longitudinal axis of the larger systems. In general, the habitat quality of the sub-embayments is highest near their mouths and poorest in the inland-most tidal reaches. This is indicated by longitudinal gradients of the various indicators. Nitrogen concentrations are highest inland and lowest near the mouths. Eelgrass abundance is highest near the mouths of the embayments. Infaunal communities are more stressed in the inland reaches. Dissolved oxygen concentrations are lowest inland and highest near the mouths of the embayments. Chlorophyll *a* concentrations are the highest in the inland reaches.

The following is a brief synopsis of the present habitat quality within each of the five-embayment systems:

***Stage Harbor System* –** Little Mill Pond, Mill Pond, and Oyster Pond have elevated nitrogen concentrations and have lost historic eelgrass beds that once covered most of their respective basins. Oxygen depletion is observed during summer in each system with Mill Pond (and presumably Little Mill Pond) having ecologically significant declines (to less than 3 mg/L). Oyster Pond had less oxygen depletion possibly due to its greater fetch for ventilation from the atmosphere. Chlorophyll *a* concentrations were consistent with the observed oxygen depletion. The lower reaches of the Oyster River and Upper Stage Harbor show good habitat quality as evidenced by their persistent eelgrass beds, infaunal community structure and oxygen and chlorophyll *a* concentrations. The innermost high quality habitat is found in the lower Mitchell River/upper Stage Harbor.

***Sulphur Springs System* –** Cockle Cove consists primarily of a salt marsh and central tidal creek. Both types of habitat are not expected to support eelgrass even under natural conditions. This system contains little water at low tide. Even though the assimilative capacity is unknown, it appears to be higher than that of eelgrass habitats, as do other New England salt marshes. Sulphur Springs is a shallow basin containing significant macro algal accumulations, no eelgrass, and appears to be transitioning to salt marsh. However, Sulfur Springs basin is still functioning as an embayment, but a eutrophic one. Nitrogen concentrations are high, oxygen concentrations become significantly depleted (6% of time <3 mg/L) and phytoplankton blooms are common and large (chlorophyll *a* concentrations >20 ug/L). Eelgrass has not been observed for over a decade.

***Taylors Pond System* –** Taylors Pond represents the inland-most sub-embayment and is a drowned kettle pond. The lower portion of this system is comprised of tidal salt marshes along Mill Creek. Like the Sulfur Springs System, the inner basin functions as an embayment and the tidal creek as a salt marsh with low sensitivity to nitrogen inputs. Taylors Pond is currently showing poor habitat quality. There is currently no eelgrass community and no record of eelgrass for over a decade. Water column nitrogen levels are enriched over incoming tidal waters and severe dissolved oxygen depletion to ~4 mg/L is common. Very high chlorophyll *a* concentrations of 10-15 ug/L are common during summer. The benthic infaunal community is impoverished, with a mean of only 43 individuals collected in the grab samples, compared to several hundred in the high quality sub-embayments.

***Bassing Harbor System –*** The innermost sub-embayments to this system contain high quality habitat that is currently becoming impaired by nitrogen enrichment. Ryder Cove receives the greatest watershed nitrogen load of the Bassing Harbor sub-systems. This sub-embayment has been losing its eelgrass over at least the last decade. In 1951 the full basin appears to have supported eelgrass beds many of which do not exist today. Infaunal communities indicate a moderate quality system with relatively low diversity and evenness. This is consistent with a system whose habitat is in transition from high to moderate level of quality. Upper Ryder Cove is currently showing bottom water oxygen depletion, frequently to <4 mg/L and occasionally to < 3 mg/L. The periodic oxygen declines, loss of eelgrass, and watershed nitrogen loading is consistent with the observed phytoplankton blooms, which generally (>40% of time) are >15 ug/L and frequently >20 ug/L. In contrast, the outer reach of Ryder Cove still supports relatively high habitat quality with dissolved oxygen concentrations almost always above 5 mg/L (99%) and moderate chlorophyll *a* concentrations (<15 ug/L). These water column parameters are consistent with the high eelgrass coverage. Crows Pond is the other inland-most sub-embayment in this Y-shaped estuary. However, Crows Pond has a significantly lower watershed nitrogen load than that to Ryder Cove. Crows Pond currently supports a high level of habitat quality, with eelgrass beds surrounding the central basin and sparse coverage throughout. Infaunal diversity and evenness is consistent with a high quality habitat. Dissolved oxygen concentrations are consistently above 5 mg/L and chlorophyll *a* concentrations also are moderate (generally 10-15 ug/L). However, it appears that habitat quality currently is declining. Eelgrass coverage is less than in the 1951 and 1995 records. At present it appears the Crows Pond is slightly beyond its threshold nitrogen level and is beginning to decline in habitat quality. In addition, Frost Fish Creek is a tributary system to outer Ryder Cove, which functions primarily as a salt marsh with a central basin. The outer-most basin is Bassing Harbor, which receives tidal exchanges with Pleasant Bay. Bassing Harbor currently supports high habitat quality and based upon the eelgrass records has been relatively constant since 1951. The infaunal community is consistent with high habitat quality, the maintenance of "protective" dissolved oxygen concentrations, and moderate to low chlorophyll *a* concentrations (typically 5-10 ug/L). The Bassing Harbor sub-embayment appears to be a relatively stable high habitat quality system, with demonstrated good eelgrass and infaunal communities.

***Muddy Creek –*** Muddy Creek, like Bassing Harbor, exchanges tidal waters with the greater Pleasant Bay System. However, unlike Bassing Harbor, Muddy Creek is a highly eutrophic embayment. Muddy Creek does not support significant eelgrass beds; however, a small sparse bed has persisted adjacent to the inlet. Muddy Creek is divided into an upper and lower portion by a dike whose weir has been removed or washed away. Both portions are highly eutrophic with frequent anoxia in bottom waters and large algal blooms (chlorophyll a frequently >50 ug/L). The upper portion has a lower habitat quality than the lower portion, most likely as a result of access to the higher quality waters entering the lower portion from Pleasant Bay. An infaunal community persists but it is dominated by species tolerant of organic enrichment. Species diversity and evenness are low. The whole of Muddy Creek currently supports nitrogen-impaired habitat of poor quality.

## Pollutant of Concern, Sources, and Controllability

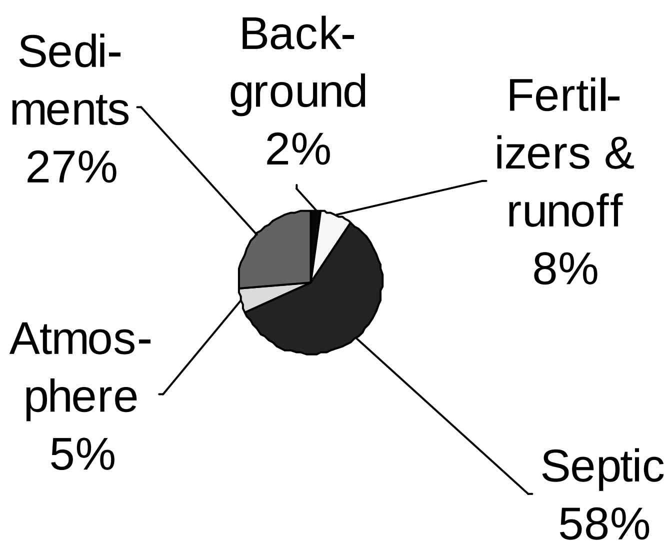
In the coastal embayments in the Town of Chatham, as in most marine and coastal waters, the limiting nutrient is nitrogen. As such, nitrogen concentrations beyond those expected naturally can contribute to undesirable conditions, including the severe impacts described above, through the promotion of excessive growth of plants and algae, including the growth of nuisance vegetation.

Each of the embayments covered in this TMDL has had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the Town of Chatham, the USGS, and the Cape Cod Commission. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the accompanying technical report.

These investigations revealed that loadings of nutrients, especially nitrogen, are much larger than they would be under natural conditions, and as a result the water quality has deteriorated. A principal indicator of decline in water quality is the disappearance of eelgrass from much of its natural habitat in these embayments. This is a result of nutrient loads causing excessive growth of algae in the water (phytoplankton) and algae growing on eel grass (epiphyton), both of which result in the loss of eelgrass through the reduction of available light levels.

As is illustrated by the following figure, most of the nitrogen affecting Chatham's embayments originate from septic systems and nutrient-rich benthic sediments, with considerably less nitrogen originating from natural background sources, runoff, fertilizers, and atmospheric deposition.

**Percent contribution of various sources of nitrogen in Chatham's embayments**




The level of "controllability" of each source, however, varies widely:

<u>Atmospheric nitrogen</u> cannot be adequately controlled locally – it is only through region- and nation-wide air pollution control initiatives that reductions are feasible;

<u>Sediment nitrogen</u> control by such measures as dredging is not feasible on a large scale. However, the concentrations of nitrogen in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document;

<u>Fertilizer – related nitrogen</u> loadings can be reduced through bylaws and public education;

<u>Stormwater</u> sources of nitrogen can be controlled by best management practices (BMPs) and stormwater infrastructure improvements;

Septic system sources of nitrogen are the largest controllable sources. These can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, upgrading/repairing failed systems, transporting and treating septage at treatment facilities with nitrogen removal technology either in or out of the watershed, or installing nitrogen-reducing septic systems.

Cost/benefit analyses will have to be conducted on all of the possible nitrogen loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

## Description of the Applicable Water Quality Standards

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen, but have only narrative standards that relate to the other variables, as described below:

314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(c) states, "Nutrients – Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication".

314 CMR 4.05(b) 1:

(a) Class SA

1. Dissolved Oxygen -
a. Shall not be less than 6.0 mg/l unless background conditions are lower;
b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 75% of saturation due to a discharge; and
c. site-specific criteria may apply where background conditions are lower than specified levels or to the bottom stratified layer where the Department determines that designated uses are not impaired.

(b) Class SB

1. Dissolved Oxygen -
a. Shall not be less than 5.0 mg/L unless background conditions are lower;
b. natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 60% of saturation due to a discharge; and
c. site-specific criteria may apply where back-ground conditions are lower than specified levels or to the bottom stratified layer where the Department determines that designated uses are not impaired.

Thus, the assessment of eutrophication is based on site specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the US Environmental Protection Agency in their draft Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (EPA-822-B-01-003, Oct 2001). As such, the guidance document notes that lakes, reservoirs, streams, and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management, however, estuarine and coastal marine waters tend to be far more unique, and development of individual waterbody criteria rather than for classes of waterbodies (such as glacial temperate lakes) is a greater likelihood.

It is this framework, coupled with an extensive outreach effort that the Department, with the technical support of SMAST, is employing to develop nutrient TMDLs for coastal waters.

## Methodology - Linking Water Quality and Pollutant Sources

Extensive data collection and analyses have been described in detail in the accompanying technical report. Those data were used by SMAST to assess the loading capacity of each embayment. Physical (**Chapter V**), chemical and biological (**Chapters IV, VII, and VIII)** data were collected and evaluated. The primary water quality objective was represented by conditions that: 1) preserve the natural distribution of eelgrass because it provides valuable habitat for shellfish and finfish, 2) prevent algal blooms, 3) protect benthic communities from impairment or loss, and 4) maintain dissolved oxygen concentrations that are protective of the estuarine communities.

The details of the data collection, modeling and evaluation are presented and discussed in the SMAST report in Chapters IV, V, VI, VII and VIII . The main aspects of the data evaluation and modeling approach are summarized below, taken from pages 4 and 5 of the Report on the Chatham embayments:

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and nitrogen characteristics, and is characterized as follows:

- requires site specific measurements within each watershed and embayment;
- uses realistic “best-estimates” of nitrogen loads from each land-use (as opposed to loads with built-in “safety factors” like Title 5 design loads);
- spatially distributes the watershed nitrogen loading to the embayment;
- accounts for nitrogen attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes nitrogen regenerated within the embayment;
- is validated by both independent hydrodynamic, nitrogen concentration, and ecological data;
- is calibrated and validated with field data prior to generation of “what if” scenarios.

The Linked Model has been applied previously to watershed nitrogen management in 15 embayments throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated, and has use as a management tool for evaluating watershed nitrogen management options.

The Linked Model, when properly parameterized, calibrated, and validated, for a given embayment, becomes a nitrogen management planning tool as described in the model overview below. The model can assess "solutions" for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. In addition, since the Model uses a holistic approach that incorporates the entire watershed, embayment and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries.

The Model provides a quantitative approach for determining an embayment's: (1) nitrogen sensitivity, (2) nitrogen threshold loading levels (TMDL) and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics (Figure I-2 of the accompanying document). This methodology integrates a variety of field data and models, specifically:

• Monitoring - multi-year embayment nutrient sampling

• Hydrodynamics -

  - embayment bathymetry
  - site specific tidal record
  - current records (in complex systems only)
  - hydrodynamic model

• Watershed Nitrogen Loading

  - watershed delineation
  - stream flow (Q) and nitrogen load
  - land-use analysis (GIS)
  - watershed nitrogen model

• Embayment TMDL - Synthesis

  - linked Watershed-Embayment Nitrogen Model
  - salinity surveys (for linked model validation)
  - rate of nitrogen recycling within embayment
  - dissolved oxygen record
  - Macrophyte survey
  - Infaunal survey (in complex systems)

***Application of the Linked Watershed-Embayment Model***

The approach developed by the MEP for applying the linked model to specific embayments, for the purpose of developing target nitrogen loading rates into the embayment, includes:

1) selecting one or two sub-embayments within each embayment system, located close to the inland-most reach or reaches, which typically has the poorest water quality within the system. These are called "sentinel" sub-embayments;

2) using site-specific information and 3 years of embayment-specific data to select target/threshold nitrogen concentrations for each embayment system. This is done by refining the draft or "threshold" nitrogen concentrations that were developed as the initial step of the MEP process. The target concentrations that were selected generally occur in higher quality waters near the mouths of the embayment systems;

3) running the calibrated water quality model using different watershed nitrogen loading rates, to determine the loading rate, which would result in achieving the target nitrogen concentration within the sentinel system. Differences between the modeled nitrogen load required to achieve the target nitrogen concentration, and the present watershed nitrogen load, represent nitrogen management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses, and the modeling activities described above, resulted in four major outputs that were critical to the development of the TMDLs. Two outputs are related to nitrogen **concentration**:

- the present nitrogen concentrations in the embayments
- site-specific target (threshold) concentrations

and, two outputs are related nitrogen **loadings** in each of the Chatham embayment systems:

- the present nitrogen loads to the sub-embayments
- load reductions necessary to meet the site specific target nitrogen concentrations

A brief overview of each of the outputs follows:

Nitrogen concentrations in the embayment systems

a) Observed "present" conditions:

Table 2 presents the average concentrations of nitrogen, measured in the sub-embayments from 1999 through 2002. Concentrations of nitrogen are the highest in Cockle Cove (1.69 mg/L) and Frost Fish (1.19 mg/L) Creeks, which are functioning salt marsh habitats where assimilative capacity is naturally high, and the highly eutrophic Muddy Creek (1.18 mg/L). Nitrogen is also high in Crows Pond (0.93 mg/L), where historically good habitat has started to decline in recent years. Nitrogen in the other embayments ranges in concentration from 0.45 to 0.73 mg/L, resulting in overall ecological habitat quality ranging from moderately high to poor. The individual yearly means and standard deviations of the averages are presented in Tables A-1 and A-2 of Appendix A.

b) Modeled site-specific target (threshold) nitrogen concentrations:

A major component of TMDL development is the determination of the maximum concentrations of nitrogen (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. Prior to conducting the analytical and modeling activities described above, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and nitrogen concentrations. The Linked Model was then used to determine site-specific threshold nitrogen concentrations by using the specific physical, chemical and biological characteristics of each embayment.

As listed in Table 2, the site-specific target (threshold) nitrogen concentration is 0.38 mg/L for all of the Stage Harbor and South Coastal embayment systems that are located on Nantucket Sound, compared to threshold nitrogen concentrations of 0.527 to 0.552 mg/L in the embayments that are located along Pleasant Bay.

The findings of the analytical and modeling investigations for each embayment system are discussed and explained below:

***Stage Harbor System*** **–** This embayment system has two upper reaches. Therefore, two sentinel sub-embayments were selected, mid-Oyster Pond and Mill Pond. Little Mill Pond could not be used because it is small and has steep horizontal nitrogen gradients (see Section VI of the accompanying report). Within the Stage Harbor System, the upper most sub-embayment supportive of high quality habitat was upper Stage Harbor (Section VII, VIII-1 of the accompanying report). Water column total nitrogen concentrations within this embayment region vary with the tidal stage due to high nitrogen out flowing waters and low nitrogen inflowing waters (Section VI of the accompanying report). Therefore, the total nitrogen level determined from the water quality model (that corrected for tidally driven variation in nitrogen concentration at each site) was used in the threshold development. The calibrated water quality model for this system indicates an average total nitrogen level in the upper Stage Harbor of 0.40 mg/L is most representative of the conditions within this sub-embayment. However, upper Stage Harbor does not appear to be stable based upon changes in eelgrass distribution. Therefore, a nitrogen level reflective of conditions closer to the inlet should achieve the stability required. The lower nitrogen level is equivalent to the tidally averaged total nitrogen concentration mid-way between upper Stage Harbor and Stage Harbor or 0.38 mg/L. This threshold selection is supported by the fact that the high quality and stable habitat near the mouth of the Oyster River (to the Stage Harbor basin) is also at a tidally averaged total nitrogen concentration of 0.37 mg/L. The 0.38 mg/L was used to develop watershed nitrogen loads required to reduce the average nitrogen concentrations in each sentinel system to this level. Tidal waters inflowing from Nantucket Sound have an average concentration of total nitrogen of 0.285 mg/L.

***Sulphur Springs System*** **–** The Sulphur Springs basin is both the inland-most sub-embayment and also represents the largest component of this system. Since this system exchanges tidal waters with the Nantucket Sound (0.285 mg/L), as does Stage Harbor, and since there is currently no high quality habitat within this system, the tidally averaged nitrogen threshold concentration for Sulphur Springs was determined to be the same as for the sentinel sub-embayments to the Stage Harbor System, i.e., 0.38 mg/L. The 0.38 mg/L was used to develop watershed nitrogen loads required to reduce the average nitrogen concentrations in the Sulphur Springs sentinel system to this level. Cockle Cove Creek, on the other hand, is primarily a salt marsh system, which is not adequately addressed by this model. Therefore, the loading rate recommendations for Cockle Cove Creek (and the discharged groundwater effluent of the Chatham treatment plant) represent loadings that are protective of the Sulphur Springs system as a whole. It should be noted that the designated uses for Cockle Cove Creek, as well as a few of the other inland-most sub-embayments in Chatham (in which eelgrass habitat does not occur and therefore eelgrass is not an existing or potential use), will be protected at higher nitrogen concentrations than those which ensure preservation of eel grass. The loadings to Cockle Cove Creek, from the treatment plant, cannot be increased because of the danger of impacting the salt marsh, the creek, and possibly the sentinel water body in Sulphur Springs. Therefore any increases in the flows to the treatment plant would have to be accompanied by a proportional reduction of effluent nitrogen in order to maintain the current loads.

***Taylors Pond System* –** This system was approached in a similar manner to the Sulphur Springs System and for the same reasons. Taylors Pond represents the innermost and functional embayment within this system. This system also exchanges tidal waters with Nantucket Sound (0.285 mg/L), as does the Stage Harbor System and there is no high quality stable embayment habitat within this system. Therefore, the tidally averaged nitrogen threshold concentration for this system was determined to be the same as for the sentinel sub-embayments to the Stage Harbor System or 0.38 mg/L. The 0.38 mg/L was used to develop watershed nitrogen loads required to reduce the average nitrogen concentrations in Taylors Pond to this level.

***Bassing Harbor System* –** Although this system has two inland-most sub-embayments, Ryder Cove and Crows Pond, only Ryder Cove was selected as the sentinel system. This resulted from the fact that Crows Pond has a relatively low nitrogen load from its watershed and appears currently to support higher quality habitat than does Ryder Cove. Ryder Cove currently shows a gradient in habitat quality with lower quality habitat in the upper reach and higher quality in the lower reach. Ryder Cove represents a system capable of fully supporting eelgrass beds and stable high quality habitat. At present, this basin is in transition from high to low habitat quality in response to increased nitrogen loading. Reductions of nitrogen concentrations in upper Ryder Cove to levels supportive of high quality habitat should also result in the restoration and protection of the whole of the Bassing Harbor System.

Following the approach used for the Stage Harbor System, a region of stable high quality habitat was selected within the Bassing Harbor System. The region selected was Bassing Harbor that has both high quality eelgrass and benthic animal communities. Unfortunately, total nitrogen within this system is very high. In fact, the whole of lower Pleasant Bay contains very high concentrations of total nitrogen. Analysis of the composition of the water column nitrogen pool within these embayments revealed that the concentrations of dissolved inorganic nitrogen (DIN) and particulate organic nitrogen (PON) were the same as for the Stage Harbor System. In fact, the level of these combined pools (DIN+PON) was lower in Bassing Harbor (0.135 mg/L) than in the Stage Harbor (0.158 mg/L) and the mouth of Oyster River (0.160 mg/L). It appears that the reason for the higher total nitrogen concentrations in the Pleasant Bay waters results from the accumulation of dissolved organic nitrogen. The bulk of dissolved organic nitrogen is relatively non-supportive of phytoplankton production in shallow estuaries, although some fraction is made available through its breakdown by microorganisms (or chemical and biochemical processes). Based upon these site-specific observations, an adjusted nitrogen threshold was developed for the Bassing Harbor System. The approach was to determine the baseline dissolved organic nitrogen level for the region (average of inner and outer Ryder Cove, Bassing Harbor, Frost Fish Creek, Tern Island, and Pleasant Bay), which was determined to be 0.394 mg/L. A threshold range was then developed using a conservative DIN+PON level from the Bassing Harbor sub-embayment plus the dissolved organic nitrogen background and an upper threshold based upon the Stage Harbor DIN and PON values discussed above. The threshold range for this system was set as 0.527 mg/L to 0.552 mg/L and the higher threshold was used to develop watershed nitrogen loads required to reduce the average nitrogen concentrations in upper Ryder Cove to this level. The nitrogen boundary condition (the concentration of nitrogen in inflowing tidal waters from Pleasant Bay) for the Bassing Harbor System is 0.48 mg/L.

***Muddy Creek System* –** This system is highly eutrophic. Given the long narrow basin and the hydrodynamic evaluation (Section V), it was decided to make lower Muddy Creek the sentinel system. This is based also upon the fact that the upper portion was historically a freshwater system. Following the approach for the Bassing Harbor System, the MEP Team considered the Ryder Cove threshold appropriate for application to Muddy Creek. Note that lower Muddy Creek recently supported a sparse eelgrass bed. The threshold was used to develop watershed nitrogen loads required to reduce the average nitrogen concentrations in lower Muddy Creek to this level. Attainment of this threshold in Upper Muddy Creek required a nearly complete load reduction. The nitrogen boundary condition (the concentration of nitrogen in inflowing tidal waters from Pleasant Bay) for the Muddy Creek System is 0.50 mg/L.

<u>Nitrogen loadings to the sub-embayments</u>

a) Present loading rates:

In Chatham, the highest nitrogen loading from controllable sources is from septic systems, and with a few exceptions is the highest nitrogen loading source overall. Septic system loadings range from 1.3 kg/day to as high as 20. 4 kg/day. Nitrogen loading from the nutrient-rich sediments (referred to as benthic flux) exceeds the nitrogen loading from septic systems in four out the six Stage Harbor sub-embayments. As discussed previously, however, the “direct” control of nitrogen from sediments is not considered feasible. However, the magnitude of the benthic contribution is related to the watershed load. Therefore, reducing the incoming load should reduce the benthic flux. The total nitrogen loading from all sources ranges from 3.45 kg/day in Frost Fish Creek, to 39.9 kg/day in Oyster Pond. A further breakdown of nitrogen loading, by source, is presented in Table 3.

**Table 2. Observed "existing" nitrogen concentrations and calculated target threshold nitrogen concentrations derived for the Chatham embayment systems**

| Embayment Systems And Sub-embayments | Observed System Nitrogen Concentration [1] (mg/L) | System Threshold Nitrogen Concentration (mg/L) |
|---|---|---|
| **Stage Harbor** | | 0.38 |
| Oyster Pond | 0.51 - 0.67 | |
| Oyster River | 0.45 | |
| Stage Harbor | 0.47 – 0.60 | |
| Mitchell river | 0.45 | |
| Mill Pond | 0.46 | |
| Little Mill Pond | 0.73 | |
| **Sulphur Springs** | | 0.38 |
| Sulphur Springs | 0.45 | |
| Bucks Cr | 0.47 | |
| Cockle Cove Cr | 0.74 – 1.69 | |
| Wastewater TF | | |
| **Taylors Pond** | | 0.38 |
| Mill Cr | 0.51 | |
| Taylors Pond | 0.51 | |
| **Bassing Hbr** | | 0.527 - 0.552 |
| Crows Pd | 0.93 | |
| Ryder Cove | 0.42 – 0.57 | |
| Frost Fish Cr | 0.81 – 1.19 | |
| Bassing Harbor | 0.50 | |
| **Muddy Cr.** | | 0.552 |
| Lower Muddy Cr. | 0.59 | |
| Upper Muddy Cr. | 1.18 | |

[1] calculated as the average of the separate yearly means of 1999 – 2002 data. Individual yearly means and standard deviations of the average are presented in Tables A – 1 and A – 2 of Appendix A

**Table 3. Nitrogen loadings to the Chatham sub-embayments from within the watersheds (natural background, land use-related runoff, and septic systems), from the atmosphere, and from nutrient-rich sediments within the embayments.**

| Embayment Systems and Sub-embayments | Natural Background [1] Watershed Load (kg/day) | Present Land Use Load [2] (kg/day) | Present Septic System Load (kg/day) | Present Atmospheric Deposition (kg/day) | Present Benthic Flux [3] (kg/day) | Total nitrogen load from all sources (kg/day) |
|---|---|---|---|---|---|---|
| **Stage Harbor** | | | | | | |
| Oyster Pond | 0.64 | 1.23 | 10.94 | 0.29 | 26.8 | 39.90 |
| Oyster River | 0.54 | 1.24 | 9.73 | 1.05 | 0.7 | 13.26 |
| Stage Harbor | 0.16 | 0.28 | 2.30 | 3.25 | 12.8 | 18.79 |
| Mitchell river | 0.16 | 0.65 | 5.37 | 0.88 | -3.4 | 3.66 |
| Mill Pond | 0.06 | 0.17 | 1.53 | 0.63 | 3.7 | 6.09 |
| Little Mill Pond | 0.04 | 0.25 | 1.30 | 0.12 | 2.0 | 3.71 |
| **Sulphur Springs** | | | | | | |
| Sulphur Springs | 0.45 | 1.14 | 13.84 | 0.38 | -3.6 | 12.21 |
| Bucks Cr | 0.21 | 0.36 | 3.61 | 0.13 | 2.9 | 7.21 |
| Cockle Cove Cr | 0.18 | 0.73 | 2.78 | 0.06 | - 0.9 | 5.88 [4] |
| Wastewater TF | 0.00 | | 3.03 | - | - | |
| **Taylors Pond** | | | | | | |
| Mill Cr | 0.21 | 0.68 | 5.40 | 0.17 | -0.3 | 6.16 |
| Taylors Pond | 0.27 | 0.83 | 7.31 | 0.19 | 1.7 | 10.30 |
| **Bassing Hbr** | | | | | | |
| Crows Pd | 0.14 | 0.53 | 5.06 | 1.39 | 3.5 | 10.62 |
| Ryder Cove | 0.45 | 0.76 | 11.27 | 1.30 | 7.4 | 21.18 |
| Frost Fish Cr | 0.08 | 0.42 | 3.05 | 0.10 | -0.2 | 3.45 |
| Bassing Harbor | 0.10 | 0.15 | 2.42 | 1.08 | -0.1 | 3.65 |
| **Muddy Cr.** | | | | | | |
| Lower Muddy Cr. | 0.05 | 1.82 | 13.39 | 0.21 | -1.9 | 13.57 |
| Upper Muddy Cr. | 0.87 | 1.49 | 20.41 | 0.2 | 4.7 | 27.67 |

1 assumes entire watershed is forested (i.e., no anthropogenic sources)
2 composed of fertilizer and runoff
3 nitrogen loading from the sediments
4 includes the 3.03 kg/day from the wastewater treatment facility

b) Nitrogen loads necessary for meeting the site-specific target nitrogen concentrations.

As previously indicated, the present nitrogen loadings to the Chatham embayments must be reduced and controlled in order to restore the impaired conditions and to avoid further nutrient-related adverse environmental impacts. The critical final step in the development of the TMDL was the modeling and analysis process used to determine the loadings that would be required to achieve the target nitrogen concentrations. Table 4 lists the present nitrogen loadings and reduced loadings that are necessary to achieve target concentrations (which will be described more fully in the following section). It should be noted once again that the goal of this TMDL is to achieve the target nitrogen concentration in the designated sentinel system. The loadings presented represent one, but not the only, loading reduction scenario that can meet that goal. The percentages that the present loadings would have to be reduced to meet threshold concentrations range from 0 % at Cockle Cove Creek up to 85% at Oyster Pond.

**Table 4. Present Watershed nitrogen Loading rates, calculated loading rates that are necessary to achieve target threshold nitrogen concentrations, and the percent reductions of the existing loads necessary to achieve the target threshold loadings.**

| Embayment Systems and Sub-embayments | Present watershed load [1] (kg/day) | Target Threshold Watershed Load [2] (kg/day) | Percent watershed load reductions needed to achieve threshold loads |
|---|---|---|---|
| **Stage Harbor** | | | |
| Oyster Pond | 12.81 | 1.98 | 85 % |
| Oyster River | 11.51 | 2.76 | 76 % |
| Stage Harbor | 2.74 | 0.44 | 84 % |
| Mitchell river | 6.18 | 3.47 | 44 % |
| Mill Pond | 1.76 | 0.81 | 54 % |
| Little Mill Pond | 1.59 | 0.93 | 41 % |
| Embayment system total: | 36.59 | 10.39 | 72 % |
| **Sulphur Springs** | | | |
| Sulphur Springs | 15.43 | 8.26 | 47 % |
| Bucks Cr | 4.18 | 2.18 | 48 % |
| Cockle Cove Cr | 6.72 | 6.72 | 0 % |
| Wastewater TF | 3.03 | 3.03 | 0 % |
| Embayment system total: | 29.36 | 20.13 | 31 % |
| **Taylors Pond** | | | |
| Mill Cr | 6.29 | 3.03 | 52 % |
| Taylors Pond | 8.41 | 4.01 | 53 % |
| Embayment system total: | 14.69 | 7.04 | 52 % |
| **Bassing Hbr** | | | |
| Crows Pd | 5.73 | 4.01 | 30 % |
| Ryder Cove | 12.48 | 6.92 | 45 % |
| Frost Fish Cr | 3.55 | 2.67 | 25 % |
| Bassing Harbor | 2.67 | 1.73 | 35 % |
| Embayment system total: | 24.43 | 15.33 | 37 % |
| **Muddy Cr.** | | | |
| Lower Muddy Cr. | 15.26 | 6.58 | 57 % |
| Upper Muddy Cr. | 22.77 | 9.43 | 59 % |
| Embayment total: | 38.03 | 16.01 | 58 % |

[1] Composed of combined natural background, fertilizer, runoff, and septic system loadings

[2] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 2 above.

## Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a waterbody can receive without violating water quality standards. Because there are no "numerical" water quality standards for nitrogen, the TMDLs for the Chatham embayments are aimed at determining the loads that would correspond to embayment-specific nitrogen concentrations determined to be protective of the water quality and ecosystems. The effort includes detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time), for each embayment. The results of the mathematical model are correlated with estimates of impacts on water quality, including negative impacts on eelgrass (the primary indicator), as well as dissolved oxygen, chlorophyll, and benthic infauna. The TMDLs are established to protect and/or restore the estuarine ecosystem, including eelgrass, the leading indicator of ecological health, thus meeting water quality goals for aquatic life support.

The TMDL can be defined by the equation:

$$TMDL = BG + WLAs + LAs + MOS$$

Where

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
LAs = portion allotted to (cultural) non-point sources
MOS = margin of safety

### Background loading

Natural background nitrogen loading estimates are presented in Table 3 above. Background loading was calculated on the assumption that the entire watershed is forested, with no anthropogenic sources of nitrogen.

### Wasteload Allocations

Wasteload allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. There are no point source discharges directly to surface waters in Chatham. The Town does operate a wastewater treatment facility that discharges to groundwater in the Cockle Cove sub-watershed but this is not considered a point source under EPA definition. EPA policy also requires that stormwater regulated under the NPDES program be identified and included as a wasteload allocation. As discussed below, for the purpose of this TMDL, stormwater loadings are not differentiated into point and non-point sources.

### Load Allocations

Load allocations identify the portion the loading capacity allocated to existing and future nonpoint sources. In the case of the Chatham embayments, the nonpoint source loadings are primarily from septic systems. Additional nitrogen sources include: natural background, stormwater runoff (including nitrogen from fertilizers), the Chatham WWTP's groundwater discharge, atmospheric deposition, and nutrient-rich sediments.

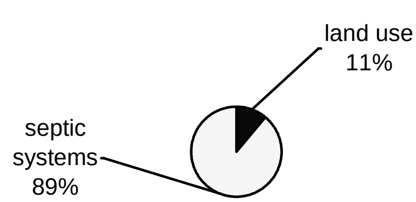
Generally, stormwater that is subject to the EPA Phase II Program would be considered a part of the "wasteload allocation", rather than the "load allocation". On Cape Cod however the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater. Given this, the TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source. Ultimately, when the Phase II Program is implemented in Chatham, new studies, and possibly further modeling, will identify what portion of the stormwater load may be controllable through the application of Best Management Practices (BMPs).

The WWTP currently discharges about 3 kg N/day into the groundwater adjacent to the extensive salt marshes of Cockle Cove Creek. This marsh system is functioning well and there are no observed indications that it is impaired by the current nitrogen loadings. Therefore, to preserve the existing status of these salt marshes, and to protect the rest of the Sulphur Springs embayment system, the nitrogen loadings to Cockle Cove Creek, including those from the wastewater treatment facility, should not exceed the present levels.

The sediment loading rates incorporated into the TMDL are lower than the existing sediment flux rates listed in Table 3 above because projected reductions of nitrogen loadings from the watershed will result in approximately proportional reductions of nutrient concentrations in the sediments, and therefore, over time, approximately proportional reductions in loadings from the sediments will occur. The loadings from atmospheric sources incorporated into the TMDL, however, are the same rates presently occurring, because, as discussed above, local control of atmospheric loadings is not considered feasible.

"Locally controllable" sources of nitrogen within the watersheds are categorized as septic system wastes and "land use", which includes stormwater runoff and fertilizers. The following figure emphasizes the fact that the overwhelming majority of locally controllable nitrogen comes from septic systems.

**Percent contribution of locally controllable sources of nitrogen**




**Margin of Safety**

TMDLs must provide a margin of safety to address uncertainties in the technical analyses as they pertain to the relationship between the pollutant loads and the quality of the receiving waters. The TMDL calculations for Chatham do not include explicit numerical values. Instead, a margin of safety was attained through conservative assumptions used in the overall analytical and modeling process. Examples of this include:

1. Use of conservative data in the linked model

In the case of nitrogen attenuation by freshwater ponds, attenuation was derived from measured nitrogen concentrations, pond delineations and pond bathymetry. These attenuation factors were higher than that used in the land-use model. The reason was that the pond data were temporally limited and a more conservative value of 40% was more protective and defensible. In another instance the estimate of nitrogen attenuation by Stillwater Pond used conservative assumptions, estimating that the un-gauged freshwater outflow was through groundwater rather than surface water flow. Similarly, the water column nitrogen validation dataset was also conservative. The model is validated to measured water column nitrogen. However, the model predicts average summer nitrogen concentrations. The very high or low measurements are marked as outliers. The effect is to make the nitrogen threshold more accurate and scientifically defensible, but also more conservative. If a single measurement 2 times higher than the next highest data point in the series, raises the average 0.05 mg N/L, this would allow for a higher "acceptable" load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the nitrogen threshold for a system.

2. Conservative threshold sites/nitrogen concentrations

Conservatism was used in the selection of the threshold sites and nitrogen concentrations. Sites were chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher nitrogen concentrations.

3 Conservative approach

Cockle Cove Creek marsh - the area in which the Chatham WWTF groundwater discharge plume enters marine waters - was given a threshold equal to its current load. The reason is that the system is a salt marsh, which appears to be functioning well. While this system might take additional nitrogen load without significant impairment, the evidence is not yet available to support increased loadings.

**Seasonal Variation**

Nutrient loads to embayments are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Thus, nutrient loads must be controlled on an annual basis. Second, as a practical matter, the types of controls necessary to control the nitrogen load, the nutrient of primary concern, by their very nature do not lend themselves to intra-annual manipulation since the majority of the nitrogen is from non-point sources.

**TMDL Values for Chatham Embayments**

As outlined above, the total maximum daily loadings of nitrogen that would provide for the restoration and protection of each embayment, were calculated by considering all sources of nitrogen grouped by natural background, point sources, and non-point sources. A more meaningful way of presenting the loadings data, from an implementation perspective, is presented in Table 5. In this table the nitrogen loadings from the atmosphere and nutrient-rich sediments are listed separately from the target watershed threshold loads, which are composed of natural background nitrogen along with locally controllable nitrogen from the WWTP, septic systems, stormwater runoff, and fertilizers. In the case of Chatham, the TMDLs were calculated by projecting reductions in locally controllable septic system, stormwater runoff, and fertilizer sources.

**Table 5. The total maximum daily loads (TMDL) for the Chatham embayment systems, represented as the sum of the calculated target thresholds loads (from controllable watershed sources), atmospheric deposition, and sediment sources (benthic flux).**

| Embayment Systems and Sub-embayments: | Target Watershed Threshold Load [1] (kg/day) | Atmospheric Deposition (kg/day) | Benthic Flux [2] (kg/day) | **TMDL [3] (kg/day)** |
|---|---|---|---|---|
| **Stage Harbor** | | | | |
| Oyster Pond | 1.98 | 0.29 | 10.2 | **12.47** |
| Oyster River | 2.76 | 1.05 | 0.3 | **4.11** |
| Stage Harbor | 0.44 | 3.25 | 4.9 | **8.59** |
| Mitchell river | 3.47 | 0.88 | -1.3 | **3.05** |
| Mill Pond | 0.81 | 0.63 | 1.4 | **2.84** |
| Little Mill Pond | 0.93 | 0.12 | 0.8 | **1.85** |
| Stage Harbor system total: | 10.39 | 6.22 | 16.3 | **32.91** |
| **Sulphur Springs** | | | | |
| Sulphur Springs | 8.26 | 0.38 | -2.3 | **6.34** |
| Bucks Cr | 2.18 | 0.13 | 1.9 | **4.21** |
| Cockle Cove Cr | 6.66 | 0.06 | -0.6 | **6.12** |
| Wastewater TF | 3.03 | - | - | **N/A** |
| Sulphur Sprg system total: | 20.13 | 0.57 | -1.0 | **16.67** |
| **Taylors Pond** | | | | |
| Mill Cr | 3.03 | 0.17 | -0.2 | **3.00** |
| Taylors Pond | 4.01 | 0.19 | -0.9 | **3.30** |
| Taylors Pd system total: | 7.04 | 0.36 | -1.1 | **6.3** |
| **Bassing Hbr** | | | | |
| Crows Pd | 4.01 | 1.39 | 2.6 | **8.00** |
| Ryder Cove | 6.92 | 1.30 | 5.6 | **13.82** |
| Frost Fish Cr | 2.67 | 0.10 | -0.1 | **2.67** |
| Bassing Harbor | 1.73 | 1.08 | -0.1 | **2.71** |
| Bassing Hbr system total: | 15.33 | 3.87 | 8.0 | **27.2** |
| **Muddy Cr.** | | | | |
| Lower Muddy Cr. | 6.58 | 0.21 | -0.9 | **5.89** |
| Upper Muddy Cr. | 9.43 | 0.2 | 2.3 | **11.93** |
| Muddy Cr. total: | 16.01 | 0.41 | 1.4 | **17.82** |

[1] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 2. Once again the goal of this TMDL is to achieve the identified nitrogen threshold concentration in the identified sentinel system. The target load identified in this table represents one alternative loading scenario to achieve that goal but other scenarios may be possible and approvable as well.

[2] Projected sediment nitrogen loadings obtained by reducing the present loading rates (Table 3) proportional to proposed watershed load reductions

[3] Sum of target threshold watershed load, atmospheric deposition load, and benthic flux load

## Implementation Plans

The critical element of this TMDL process is achieving the embayment-specific nitrogen concentrations presented in Table 2 above, that are necessary for the restoration and protection of water quality and eelgrass habitat within the Chatham embayments. In order to achieve those "target" concentrations, nitrogen loading rates must be reduced throughout the embayment systems. Table 5, above, lists target watershed threshold loads for each sub-embayment. If those threshold loads are achieved, the overall embayment will be protected. This loading reduction scenario is not the only way to achieve the target nitrogen concentrations. The Town is free to explore other loading reduction scenarios through additional modeling as part of the Comprehensive Wastewater Management Plan (CWMP). It must be demonstrated, however, that any alternative implementation strategies will be protective of the overall embayment systems, and that none of the sub-embayments will be negatively impacted. To this end, additional linked model runs can be performed by the MEP at a nominal cost to assist the Town planning effort in achieving target nitrogen loads that will result in the desired threshold concentrations. The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the DEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results.

Because the vast majority of controllable nitrogen load is from individual septic systems for private residences, the nitrogen control strategy should assess the most cost-effective options for achieving the target watershed loads, including but not limited to, sewering and treatment for nitrogen control of sewage and septage at either centralized or de-centralized locations, and denitrifying systems for all private residences.

Tables VIII-2 and VIII- 3 of the accompanying Technical Report (and reproduced in Appendix B of this document) summarize the present loadings from septic systems, and the reduced loads that would be necessary to achieve the threshold nitrogen concentrations in each embayment if septic loads alone were targeted. The Town, however, is urged to meet the target threshold nitrogen concentrations by reducing nitrogen loadings from any and all sources, through whatever means are available and practical, including reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater BMPs, in addition to reductions in septic system loadings.

The EPA and the DEP recognize that effluent trading may provide a cost-effective means for the Town of Chatham to achieve the overall TMDL objectives. The EPA Water Quality Trading Policy Statement (http://www.epa.govowow/watershed/trading/finalpolicy2003.html) encourages trading programs that facilitate implementation of TMDLs, reduce the costs of compliance with the Clean Water Act regulations, establish incentives for voluntary reductions, and promote watershed-based nutrient load reduction initiatives.

The MEP Implementation Guidance report provides nitrogen loading reduction strategies that are available to the Town of Chatham, and could be incorporated into the Town's implementation plans. The following topics related to nitrogen reduction are discussed in the Guidance report:

- Wastewater Treatment
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment
    - Community Treatment Plants

- Tidal Flushing
    - Channel Dredging
    - Inlet Alteration
    - Culvert Design and Improvements
- Stormwater Control and Treatment *
    - Source Control and Pollution Prevention
    - Stormwater Treatment
- Attenuation via Wetlands and Ponds
- Water Conservation and Water Reuse
- Management Districts
- Land Use Planning and Controls
    - Smart Growth
    - Open Space Acquisition
    - Zoning and Related Tools
- Nutrient "Trading"

* The Town of Chatham is one of 237 communities in Massachusetts covered by the phase II stormwater program requirements.

**Monitoring Plan for TMDL Developed Under the Phased Approach**

The Department recommends that the Town of Chatham develop a detailed monitoring plan as part of the Comprehensive Wastewater Management Planning process and as part of the detailed plan for TMDL implementation. The monitoring plan should be designed to determine if water quality improvements occur as a result of implementing this TMDL, and should be developed and conducted in phases according to the identification of nitrogen reduction options. The Department recognizes the long-term nature of the time horizon for full implementation of the TMDL, however, reasonable milestones in the shorter term are necessary.

Growth should be guided by a consideration of water quality-associated impacts.

## Reasonable Assurances

Because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. Chatham has demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The town expects to use the information in this TMDL to generate support among its populace to take the necessary steps to remedy existing problems related to nitrogen loading from septic systems, stormwater, and runoff (including fertilizers), and to prevent any future degradation of these valuable resources.

## Appendix A

Tables A – 1 and A – 2: Summaries of nitrogen concentrations for Bassing Harbor and Muddy Creek sub-embayments (from Chapter VI of the accompanying MEP Technical Report, Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Stage Harbor, Sulphur Springs, Taylors Pond, Bassing Harbor, and Muddy Creek, Chatham, Massachusetts, December 2003)

Table A – 1.

Table VI-1a. Measured and modeled Nitrogen concentrations for Bassing Harbor and Muddy Creek, used in the model calibration plots of Figures VI-3 (Bassing Harbor total N),VI-4 (Bassing Harbor bio-active N), and VI-5 (Muddy Creek). All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means.

| System | Embayment | 1999 mean | 2000 mean | 2001 mean | 2002 mean | Overall mean | s.d. | N | model min | model average | model max |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bassing Harbor (TOTAL N) | Ryder Cove (inner) | - | 0.465 | 0.634 | 0.653 | 0.569 | 0.183 | 46 | 0.556 | 0.564 | 0.573 |
| | Ryder Cove (outer) | - | 0.437 | 0.391 | 0.427 | 0.419 | 0.067 | 47 | 0.493 | 0.522 | 0.551 |
| | Frost Fish Cr. (inner) | - | 0.915 | 0.684 | 0.788 | 0.809 | 0.218 | 18 | 0.676 | 0.724 | 0.792 |
| | Frost Fish Cr. (outer) | - | 1.244 | 0.867 | 1.379 | 1.187 | 0.435 | 23 | 0.535 | 0.605 | 0.818 |
| | Crows Pond | - | 0.755 | 0.936 | 1.135 | 0.929 | 0.346 | 44 | 0.576 | 0.585 | 0.591 |
| | Bassing Harbor | - | 0.543 | 0.462 | 0.482 | 0.499 | 0.172 | 23 | 0.480 | 0.497 | 0.532 |
| Bassing Harbor (Bio-Active N) | Ryder Cove (inner) | - | 0.178 | 0.168 | 0.242 | 0.189 | 0.067 | 46 | 0.192 | 0.200 | 0.208 |
| | Ryder Cove (outer) | - | 0.167 | 0.139 | 0.191 | 0.163 | 0.036 | 47 | 0.129 | 0.158 | 0.187 |
| | Frost Fish Cr. (inner) | - | - | 0.364 | 0.409 | 0.387 | 0.065 | 10 | 0.312 | 0.360 | 0.428 |
| | Frost Fish Cr. (outer) | - | 0.391 | 0.307 | 0.290 | 0.338 | 0.173 | 23 | 0.171 | 0.241 | 0.454 |
| | Crows Pond | - | 0.220 | 0.200 | 0.232 | 0.218 | 0.095 | 44 | 0.212 | 0.221 | 0.227 |
| | Bassing Harbor | - | 0.156 | 0.108 | 0.131 | 0.133 | 0.037 | 23 | 0.116 | 0.133 | 0.168 |
| Muddy Creek | Lower Muddy Cr. | - | 0.569 | 0.591 | 0.622 | 0.586 | 0.092 | 21 | 0.557 | 0.597 | 0.658 |
| | Upper Muddy Cr. | - | - | - | 1.184 | 1.184 | 0.501 | 6 | 1.179 | 1.205 | 1.232 |

Table A – 2..

Table VI-1b. Measured and modeled Nitrogen concentrations for Stage Harbor, Sulphur Springs, and Taylors Pond, used in the model calibration plots of Figures VI-6 (Stage Harbor total N),VI-7 (Sulphur Springs), and VI-8 (Taylors Pond). All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means.

| System | Embayment | 1999 mean | 2000 mean | 2001 mean | 2002 mean | data mean | s.d. | N | model min | model average | model max |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stage Harbor* | Oyster Pond | 0.597 | 0.786 | 0.708 | 0.604 | 0.667 | 0.252 | 63 | 0.671 | 0.678 | 0.687 |
| | Lower Oyster Pond | - | - | 0.552 | 0.498 | 0.505 | 0.083 | 8 | 0.371 | 0.547 | 0.658 |
| | Oyster River | 0.451 | 0.457 | 0.386 | 0.536 | 0.457 | 0.103 | 28 | 0.286 | 0.374 | 0.568 |
| | Stage Harbor | 0.425 | 0.664 | 0.632 | 0.677 | 0.597 | 0.182 | 58 | 0.288 | 0.339 | 0.427 |
| | Upper Stage Harbor | 0.418 | 0.457 | 0.503 | 0.548 | 0.474 | 0.116 | 62 | 0.382 | 0.401 | 0.423 |
| | Mitchell River | - | - | 0.429 | 0.487 | 0.451 | 0.092 | 13 | 0.403 | 0.432 | 0.467 |
| | Mill Pond | 0.471 | 0.503 | 0.418 | 0.507 | 0.463 | 0.102 | 70 | 0.466 | 0.473 | 0.485 |
| | Little Mill Pond | 0.792 | 0.690 | 0.742 | 0.741 | 0.733 | 0.226 | 60 | 0.696 | 0.711 | 0.723 |
| Sulphur Springs | Mid Cockle Cove Cr. | - | 1.492 | 2.043 | 1.613 | 1.685 | 0.698 | 18 | 0.704 | 1.378 | 2.493 |
| | Cockle C. Cr. mouth | - | 0.890 | 0.687 | 0.636 | 0.742 | 0.213 | 23 | 0.286 | 0.472 | 0.988 |
| | Bucks Creek | - | 0.401 | 0.479 | 0.576 | 0.473 | 0.139 | 20 | 0.285 | 0.337 | 0.508 |
| | Sulphur Springs | - | 0.360 | 0.453 | 0.584 | 0.451 | 0.123 | 23 | 0.288 | 0.369 | 0.498 |
| Taylors Pond | Mill Creek | - | 0.491 | 0.508 | 0.530 | 0.507 | 0.105 | 23 | 0.284 | 0.326 | 0.584 |
| | Taylors Pond | - | 0.509 | 0.487 | 0.530 | 0.508 | 0.122 | 48 | 0.424 | 0.467 | 0.517 |

* Stage Harbor also included the limited sampling data (N=4) from 1998.

## Appendix B

Tables B –1 and B – 2 summarize the present septic system loads, and the loading reductions that would be necessary to achieve the TMDL by reducing septic system loads, ignoring all other sources.

Table B- 1.

Table VIII-2. Comparison of sub-embayment watershed septic loads used for modeling of present and threshold loading scenarios of the South Coastal embayments and Stage Harbor systems. These loads represent groundwater load contribution from septic systems only, and do not include runoff, fertilizer, atmospheric deposition and benthic flux loading terms.

| Sub-embayment | Present Septic Load g/day) | New Septic Load (kg/day) | Threshold % Change |
|---|---|---|---|
| Stage Harbor | | | |
| Oyster Pond | 11.16 | 0.11 | -99% |
| Oyster River | 9.69 | 0.79 | -92% |
| Stage Harbor | 2.32 | 0.00 | -100% |
| Mitchell River | 5.57 | 2.66 | -52% |
| Mill Pond | 1.55 | 0.59 | -62% |
| Little Mill Pond | 1.35 | 0.65 | -52% |
| Sulphur Springs | | | |
| Sulphur Springs | 13.74 | 6.67 | -52% |
| Bucks Creek | 3.51 | 1.62 | -54% |
| Cockle Cove Creek | 2.72 | 2.72 | 0% |
| Waste Water TF | 3.03 | 3.03 | 0% |
| Taylors Pond | | | |
| Mill Creek | 5.33 | 2.14 | -60% |
| Taylors Pond | 7.11 | 2.91 | -59% |

Table B – 2.

Table VIII-3. Comparison of sub-embayment watershed septic loads used for modeling of present and threshold loading scenarios of the Pleasant Bay embayment systems. These loads represent groundwater load contribution from septic systems only, and do not include runoff, fertilizer, atmospheric deposition and benthic flux loading terms.

| Sub-embayment | Present Septic Load (kg/day) | New Septic Load (kg/day) | Threshold % Change |
|---|---|---|---|
| Bassing Harbor | | | |
| Crows Pond | 5.12 | 3.32 | -35% |
| Ryder Cove | 11.14 | 5.71 | -49% |
| Frost Fish Creek | 3.09 | 2.17 | -30% |
| Bassing Harbor | 2.41 | 1.48 | -39% |
| Muddy Creek | | | |
| Muddy Creek -lower | 11.49 | 4.71 | -59% |
| Muddy Creek - upper | 16.69 | 7.07 | -58% |